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## **The lack of international consumption risk sharing: can inflation differentials and trading costs help explain the puzzle?**

Hoffmann, Mathias

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# The Lack of International Consumption Risk Sharing: Can Inflation Differentials and Trading Costs Help Explain the Puzzle?

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**Abstract** The bulk of evidence on the lack of international risk sharing is based on regressions of idiosyncratic consumption growth on idiosyncratic output growth. This paper argues that the results from such regressions obtained from international data are, however, not directly comparable to those based on regional data: the standard practice of running such regressions on international data fails to account for persistent international differentials in consumer prices, whereas—implicitly—most of the literature based on regional data has accounted for these differences. When risk sharing regressions are set up in conceptually the same way in international and regional data sets, the estimated coefficients are also very similar. To explore this result further, we adapt the variance decomposition of Asdrubali et al. (Q J Econ 111:1081–1110, 1996) to allow for deviations from purchasing power parity across countries. While quantity (income and credit) flows are the dominant channel of risk sharing among regions, relative consumption and output price (internal terms of trade) fluctuations account for the bulk of the deviation from the complete markets outcome in international data. To the extent that persistent differences in consumer prices are an indication of goods market segmentation, our findings provide empirical evidence for the proposition by Obstfeld and Rogoff (NBER Macroeconomics Annual 2000, 2000) that segmented international

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**JEL Classification** F21 · F32 · F36 · E21

## 1 Introduction

Risk sharing between regions and nations has been the focus of much empirical research over the last decade.<sup>1</sup> The main conclusion that emerges from this literature is that regions within a country share a lot more consumption risk than do countries.

Most of the evidence on international and interregional risk sharing is based on panel regressions of real idiosyncratic consumption growth on other idiosyncratic variables, mostly national or regional output. The motivation behind such risk sharing regressions is that in a world with complete capital markets, countries and regions will insure completely against any idiosyncratic risk. If furthermore, trade in goods markets is frictionless so that prices equalize across countries and regions, then, *ex post*, there should not be any correlation between a country's or region's relative output and consumption. The size of the regression coefficient of idiosyncratic consumption on idiosyncratic output can therefore be interpreted as a measure of the deviation from the complete markets outcome.

This paper argues that the results obtained from such regressions in international data are not generally comparable to those based on regional data. The reason for this is that for most countries consumer price indexes are not available at the regional level. Therefore, in regional data, the commonly applied procedure is to transform nominal into real quantities by deflating with the country-wide CPI. This practice preserves fluctuations in the relative *value* of consumption across regions. In this paper, we advocate this practice also for international data sets. Earlier studies that have examined risk sharing in international data have typically deflated the data with national (i.e. country-specific) CPIs. In this way, only fluctuations in the relative quantities but not in the relative value of consumption are preserved.

What may at first sight appear as a measurement issue is, in fact, an important conceptual difference: in addition to quantity (i.e.: capital income and credit) flows, fluctuations in relative consumer prices may constitute a separate channel of risk sharing. I add such a price channel to the popular variance decomposition by Asdrubali et al. (1996). Whereas earlier versions

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<sup>1</sup>Some prominent papers are Asdrubali et al. (1996), Sørensen and Yosha (1998), Hess and Shin (1998), Crucini (1999) and Méltitz and Zumer (1999).

of this decomposition<sup>2</sup> have focused on the relative importance of capital income and credit flows for risk sharing, the version suggested here also allows to gauge the contribution of price fluctuations. In the framework of this decomposition, it is straightforward to give economic meaning to the different practices of deflating regional and international data: the procedure commonly used on international data simply eliminates fluctuations in relative purchasing power and therefore does not pick up their contribution to risk sharing. Since fluctuations in relative prices are particularly important at the international level where goods markets are relatively segmented, one may expect that the omission of this channel may have a particularly pronounced effect on estimates of risk sharing obtained from international data sets.

We find this conjecture confirmed in our empirical investigation, for which we use data from the Penn World tables for 22 industrialized countries from 1973–2000. Our results show that once the price channel is accounted for in a comparable way, the coefficients estimated from risk sharing regressions are similar in regional and international data sets. Hence, conceptual differences in the preparation of the data used in estimation seem to explain why most studies find very little risk sharing in international data and a lot in regional data.

Does this finding suggest that there is no lack of international risk sharing? To explore the anatomy of this result further, we compare our international results to evidence obtained from regional data sets from Australia, Canada, Germany and Italy—countries for which consumer price data can be obtained at a regional level. We find that regions within countries achieve most of their risk sharing through quantity (income and credit flows), very much as the earlier literature has documented. Also, quantity flows between countries are small, again in line with virtually all of the extant literature. In this sense there is a clear lack of international consumption risk sharing. The reason why we still find a small coefficient when our version of the risk sharing regression is performed on international data, is that international inflation differentials covary strongly with the relative value of a country's output. This channel, on the other hand, is virtually absent in regional data, presumably because the cross-regional dispersion of consumer prices is low.

We interpret the degree of international variation in consumer price inflation as an indication of goods market segmentation or, loosely speaking, of trading costs. This allows us to read the lack of international quantity—i.e. income and credit—flows in the light of a recent literature that emphasizes the role of goods market segmentation in rationalizing some of the major anomalies in international finance. In particular Obstfeld and Rogoff (2000) have argued that relatively small trading costs in goods markets can lead to huge equity portfolio home biases and may therefore also explain the apparent lack of capital flows between countries. In the Obstfeld–Rogoff model this occurs even though financial markets are complete. While our results do not imply that either regional or international financial markets are complete, they

<sup>2</sup>See e.g. Becker and Hoffmann (2006), who examine the contribution of capital income and credit flows to risk sharing at different horizons.

provide further empirical support for the view that goods market frictions rather than financial market frictions can explain the lack of risk sharing at the country relative to the regional level: As emphasized by Obstfeld and Rogoff (2000), optimal risk sharing under goods market segmentation implies that in response to idiosyncratic output shocks, consumption growth is equated across countries only to the extent that consumption price levels are equated. *Ceteris paribus*, larger international price dispersion means that smaller income and credit flows are required to implement an allocation in which risk is shared optimally.<sup>3</sup> The comparison between our results obtained from international data on the one hand and regional data on the other suggest that larger variation in relative prices—as measured by international or interregional inflation differentials—does indeed go in hand with smaller cross-border income and credit flows. Lane and Milesi-Ferretti (2004) emphasize that countries' international asset portfolio weights are highly correlated with their trade weights. The results here may help explain this finding: if international trade eliminates country-specific variation in consumer prices, then larger capital flows may be required to share risk optimally.

Starting with Backus and Smith (1993), a number of studies have emphasized that optimal risk sharing implies a high inverse relation between real exchange rates and relative consumption if purchasing power parity is violated. The tenor of these studies is that the link between real exchange rates and consumption growth is tenuous at best. It would therefore seem surprising that our approach reveals such an important role for relative prices in international risk sharing. However, our results are perfectly in line with the observation that real exchange rates and relative consumption are weakly correlated and indeed we corroborate this finding in our data set. As we argue, correlations between consumption and real exchange rates may be low for a variety of reasons that could be unrelated to market incompleteness.<sup>4</sup>

This is why in this paper we prefer to build on the literature on risk sharing regressions in the spirit of Cochrane (1991), Mace (1991), Townsend (1994), Asdrubali et al. (1996), Crucini (1999) and others. Rather than to examine correlations between real exchange rates and consumption, we argue, that a somewhat more robust, reading of the conditions for optimal risk sharing is that the relative value of marginal utility should not be systematically related to a country's idiosyncratic risk.

The remainder of this paper is structured as follows: in Section 2 we take stock of the current practice of formulating risk sharing regressions in regional and international data. We then propose how to adapt the international risk

<sup>3</sup>We have nothing to say about welfare implications. Clearly, it will be welfare enhancing if there are no transport costs and if prices equalize, even though this may entail more flows of capital (and ultimately shipment of goods). Our interest here is in the optimality (or otherwise) of risk sharing given the structure of goods markets, not in assessing the welfare implications of the respective structure.

<sup>4</sup>Indeed, we find that the correlation between consumption and real exchange rates (i.e. inflation differentials) is very low even in regional data, even though there is wide agreement in the literature that there is quite a lot of risk sharing at the regional level.

sharing regression so that it can be compared to the findings from regional data and we highlight the role of international price dynamics for this adaptation. In Section 3, we modify the variance decomposition of Asdrubali et al. (1996) to take account of both a price channel and a quantity channel of international risk sharing. In Section 4, we present our data set along with our empirical results. Section 5 discusses and concludes.

## 2 Risk sharing regressions

The focus of this paper is on panel regressions of the form

$$\Delta \log \left[ \frac{\tilde{C}_t^k}{\tilde{C}_t^*} \right] = \tilde{\beta}_u \Delta \log \left[ \frac{\tilde{Y}_t^k}{\tilde{Y}_t^*} \right] + \varepsilon_t^k \quad (1)$$

where  $\tilde{C}$  and  $\tilde{Y}$  are measures of real per capita consumption and output, respectively,  $k$  is the country or region index and the asterisk denotes the population-weighted rest of the world or country average.

Regressions such as Eq. 1 were first suggested by Mace (1991) and Cochrane (1991) as tests of financial market completeness: in complete financial markets, idiosyncratic consumption growth should be independent of idiosyncratic risk and therefore, in particular of idiosyncratic fluctuations in a country's or region's output. While this intuition is exactly true only under special assumptions (such as power utility and additive separability in consumption and leisure), it has proven sufficiently powerful to spark a large and influential literature that has generated important insights into the structure of international and interregional risk sharing. In particular, Asdrubali et al. (1996), Sørensen and Yosha (1998) and others have argued very convincingly that the coefficient  $\tilde{\beta}_u$ —typically between zero and one in the data—is a measure of the deviation from the complete markets outcome; it indicates *how much* of the idiosyncratic risk represented by fluctuations in  $\Delta \log \left[ \frac{Y_t^k}{Y_t^*} \right]$  is *not* shared but spills over into fluctuations in relative consumption.

In international data, estimates of  $\tilde{\beta}_u$  are generally much higher than in regional data. This stylized fact documents a lack of international risk sharing. The fact that  $\tilde{\beta}_u$  is significantly bigger than zero and often close to unity amounts to a restatement of the famous international consumption correlation puzzle first identified by Backus et al. (1992). But the correlation-based formulation of the puzzle also encounters the so-called quantity anomaly: international consumption correlations are lower than the correlations in the underlying risks, i.e. in output growth rates. This would suggest that countries actually use financial markets to de-stabilize consumption, a very implausible proposition. Even under complete markets, countries or regions may experience idiosyncratic demand or preference shocks (see e.g. Stockman and Tesar 1995) and consumption is often measured with error. In these cases, consumption growth may be imperfectly correlated across regions but in complete markets it should still be uncorrelated with idiosyncratic country

risk characteristics, notably relative output. Presumably for these reasons, regressions such as Eq. 1 provide a standard metric of risk sharing used in many empirical studies.

## 2.1 Common vs. country-specific consumption deflators

As I am going to argue in this sub-section, the coefficients obtained from studies based on international data are not generally directly comparable to those based on regional data because the real consumption and output measures  $\tilde{C}$  and  $\tilde{Y}$  used in both types of studies are conceptually different.

For most countries, notably the U.S., for which we have the most evidence in relation to interregional risk sharing, consumer prices are not available at the regional (say, federal state) level. For this reason, most researchers use the country-wide CPI to deflate both GDP and consumption.<sup>5</sup> Hence, the regional consumption and output measures are

$$\tilde{C}_t^k = C_t^k CPI_t^k / CPI_t^* \text{ and } \tilde{Y}_t^k = P_t^k Y_t^k / CPI_t^*$$

where  $C_t^k$  is the actual quantity of consumption in region  $k$ ,  $CPI$  denotes the consumer price index and  $P^k$  is the regional output deflator.

The risk sharing regression is formulated in terms of *relative* growth rates, so that with  $\tilde{C}_t^* = C_t^* / CPI_t^*$  and  $\tilde{Y}_t^* = P_t^* Y_t^* / CPI_t^*$  the risk sharing regression (1) effectively becomes

$$\Delta \log \left[ \frac{CPI_t^k C_t^k}{CPI_t^* C_t^*} \right] = \beta_u^{reg} \Delta \log \left[ \frac{P_t^k Y_t^k}{P_t^* Y_t^*} \right] + \varepsilon_{kt}^{reg} \quad (2)$$

Hence, in regional data, the risk sharing regression effectively amounts to running regressions of region-specific nominal consumption growth on the relative nominal growth rates of output.

Conversely, most studies based on international data deflate both consumption and output with the country-specific  $CPI$ , so that  $\tilde{C}_t^k = C_t^k / CPI_t^*$  and  $\tilde{Y}_t^k = P_t^k Y_t^k / CPI_t^*$  so that the regression run on international data is

$$\Delta \log \left[ \frac{C_t^k}{C_t^*} \right] = \beta_u^{int} \Delta \log \left[ \frac{P_t^k Y_t^k / CPI_t^k}{P_t^* Y_t^* / CPI_t^*} \right] + \varepsilon_{kt}^{int} \quad (3)$$

Clearly, these are not the same regressions. I wish to explore to what extent the difference in the setup of these regressions affects the comparison between international and regional measures of risk sharing. Using data from a number of countries for which regional  $CPI$ s are available, I therefore run the international regression (3) on regional data. Conversely, I will run the regional regression (2) on an international data set.

This exercise is interesting, because the difference between the two regressions is conceptually important:  $\beta_{reg}$  tells us how the *value* of consumption

<sup>5</sup>E.g. Asdrubali et al. (1996), Sørensen and Yosha (1998), Crucini (1999) and Mélitz and Zumer (1999), Becker and Hoffmann (2006). And presumably, this list is far from complete.

growth relative to the rest of the country reacts to shocks in the *value* of regional output.  $\beta_u^{int}$  tells us how relative consumption *quantities* react to shocks in the *quantity* of consumption a country can buy for its output.<sup>6</sup> The difference between  $\beta_u^{int}$  and  $\beta_u^{reg}$  must tell us something about the role of interregional and international price dispersion for risk sharing.

As I will show, running the international regression on regional data does not make much of a difference for our estimate of  $\tilde{\beta}_u$ : in regional data, fluctuations in relative consumer prices are relatively small so that the regression outcome is not strongly affected. There is, however, a huge cross-sectional dispersion in consumer price inflation across countries. I interpret this dispersion as an indication of goods market segmentation or, loosely speaking, of trading costs. And, as I will show, fluctuations in relative consumer prices correlate negatively with relative national output quantities. Therefore, if regression (2) is run on international data, I find a coefficient that is almost as low as if it is run on regional data. To the extent that international dispersion in inflation rates has something to say about the integration of goods markets this suggests that trading costs may help explain why so little risk sharing is generally found in international data.

In adapting Eq. 2 to international data, we face the problem of also making national output measures comparable across countries. In regional data, a common set of sectoral price indexes is used to construct the regional output deflator  $P^k$ . For example, this is the procedure followed by the U.S. Bureau of Economic Analysis.<sup>7</sup> Hence, the price used to value e.g. oil production is the same across all U.S. states. Since oil accounts for a much larger share of output in some U.S. states, such as e.g. Alaska and Texas, fluctuations in the price of oil will still lead to idiosyncratic fluctuations in the value of these states' outputs. Therefore, fluctuations in  $P^k/P^*$  by construction cannot reflect deviations from the law of one price but only differences in the sectoral composition of output.

In adapting the regional risk sharing regression to international data, we therefore use a common set of international prices to compare the value of output across countries. At the international level, such a set of prices for the components of GDP is implicit in the data compiled in the Penn World Tables (PWT). The scope of the PWT is exactly to facilitate such international comparisons of national account data like the one we are conducting here. To this end, the PWT uses a common set of dollar prices to value the components of a country's output basket. This approach is akin to the construction of GDP price indexes at the state level. Hence, the risk sharing regression we estimate in international data has the form

$$\Delta \log \left[ \frac{CPI_t^k}{CPI_t^*} \right] + \Delta \log \left[ \frac{C_t^k}{C_t^*} \right] = \beta_u \left[ \Delta \log \left[ \frac{P_{\$}^k}{P_{\$}^*} \right] + \Delta \log \left[ \frac{Y_t^k}{Y_t^*} \right] \right] + \varepsilon_{kt} \quad (4)$$

<sup>6</sup>The term  $P_t^k/CPI_t^k$ , the internal terms of trade, gives the value of a country's output in terms of its consumption bundle.

<sup>7</sup>See their windows help file at <http://www.bea.gov/bea/regional/gsp/OnlineHelp.htm>



where  $P_{\$}/P_{\$}^*$  denotes the (relative) price level of GDP, in *international* (i.e. PPP) prices. We note again that even though home and foreign GDP are evaluated with the same set of prices, the aggregate GDP price levels do not have to equalize since domestic and rest-of-the-world GDP will generally be composed of very different outputs. It is therefore straightforward to interpret  $P_{\$}/P_{\$}^*$  as a (PPP adjusted) measure of the terms of trade.

We note here that all of the above specifications abstract from the role of nominal exchange rate fluctuations. The main reason to do so is that all of the regression-based literature on international risk sharing has conditioned on fixed nominal exchange rates. Since our aim here is to understand the anatomy of the results that earlier studies have obtained from regional and international data, it is natural that we keep with the approach chosen in these studies.<sup>8</sup> Furthermore, it is well known that exchange rates appear largely disconnected from any plausible macroeconomic fundamentals and this disconnect is also likely to blur the consumption-real exchange rate relation highlighted by Backus and Smith (1993). Therefore, to explore the role of nominal exchange rates in risk sharing, one may need a complete model of currency pricing which is clearly beyond the scope of this paper. Finally, nominal exchange rate movements can only matter in international data. So in comparing results from risk sharing regressions in regional and international data, we feel it is instructive to start by abstracting from nominal exchange rate risk.

Before moving on to the next section, we introduce some notational simplification: all risk sharing regressions are formulated in idiosyncratic terms, i.e. in relation to a 'rest of the world' aggregate. This just reflects the fact that only idiosyncratic risk can be insured. We will therefore abbreviate the logarithm of relative levels with the lower case letter, so that  $y = \log \frac{Y^k}{Y^*}$ ,  $c = \log \frac{C^k}{C^*}$ . It will also prove convenient to abbreviate with  $gdp$  the logarithm of the relative value of output, i.e.  $gdp = \log \frac{P_{\$} Y^k}{P_{\$}^* Y^*}$ .

### 3 Prices vs. quantities: channels of risk sharing

In a sequence of seminal papers, Asdrubali et al. (1996)<sup>9</sup> and Sørensen and Yosha (1998) also suggested a variance decomposition of relative GDP growth that allows to examine, to which extent capital income and credit flows contribute to consumption risk sharing. They find that at an international level, capital income flows virtually do not contribute at all to consumption insurance whereas borrowing and lending *ex-post* smooths about one quarter of the variability induced by idiosyncratic output growth. Their setup does, however,

<sup>8</sup>In virtually all studies, the nominal exchange rate is kept fixed by transferring quantities in a base year into a common currency denomination using base year nominal exchange rates. Clearly, since all regressions are in first differences, the choice of this exchange rate is of no practical relevance.

<sup>9</sup>For convenience, we will often refer to this paper as 'ASY.'

not explicitly consider relative price adjustment as a mechanism of risk sharing. We now propose a version of the ASY-decomposition that allows to examine to what extent relative consumer price variability affects international risk sharing.

To this end, we write

$$P_{\$}Y = \frac{Y}{INC} \times \frac{INC}{C} \times \frac{P_{\$}}{CPI} \times CPI \times C$$

where the new symbol  $INC$  denotes national income and will usually be measured by GNP. We take logarithms and apply the variance operator on both sides. Using the notational convention introduced at the end of the last section, we can write

$$\begin{aligned} var(\Delta gdp) &= cov(\Delta y - \Delta inc, \Delta gdp) \\ &\quad + cov(\Delta inc - \Delta c, \Delta gdp) \\ &\quad + cov(\Delta p_{\$} - \Delta cpi, \Delta gdp) \\ &\quad + cov(\Delta cpi + \Delta c, \Delta gdp) \end{aligned}$$

Dividing through by  $var(\Delta gdp)$  we get

$$1 = \beta_{inc} + \beta_{cons} + \beta_{price} + \beta_u$$

where

$$\begin{aligned} \beta_{inc} &= \frac{cov(\Delta y - \Delta inc, \Delta gdp)}{var(\Delta gdp)} \\ \beta_{cons} &= \frac{cov(\Delta inc - \Delta c, \Delta gdp)}{var(\Delta gdp)} \\ \beta_{price} &= \frac{cov(\Delta p_{\$} - \Delta cpi, \Delta gdp)}{var(\Delta gdp)} \\ \beta_u &= \frac{cov(\Delta cpi + \Delta c, \Delta gdp)}{var(\Delta gdp)} \end{aligned}$$

Since the wedge between output and income reflects cross-border flows of (capital or dividend) income,  $\beta_{inc}$  measures risk sharing through capital (i.e. equity) markets. In the same mould,  $\beta_c$  measures consumption smoothing through saving or dissaving in credit markets whereas  $\beta_u$  reflects the unsmoothed component of risk. The interpretation of the coefficients  $\beta_{inc}$ ,  $\beta_{cons}$  and also  $\beta_u$  is therefore quite analogous to that suggested by

ASY (1996) in their version of the variance decomposition of output.<sup>10</sup> We refer to the sum of  $\beta_{inc}$  and  $\beta_{cons}$  as the quantity channel since it measures how quantity flows in the form of credit or income streams help stabilize relative consumption. We abbreviate the contribution of the quantity channel with  $\beta_q = cov(\Delta y - \Delta c, \Delta gdp) / var(\Delta gdp)$ .

The new channel we introduce is the price channel and its contribution is given by  $\beta_{price}$ . This coefficient measures to what extent international goods market segmentation and hence the possibility of consumer prices to differ across regions can make quantity flows unnecessary for the optimal allocation of risk. The main mechanism we mean to capture with  $\beta_{price}$  is prominently highlighted by Obstfeld and Rogoff (2000): if consumer prices fall in response to a positive output shock, consumers will take advantage of low prices to increase their consumption. This will induce a negative comovement between (relative) consumption and (relative) output. The quantity-based risk sharing regression will register this comovement as a failure of financial markets to provide consumption insurance, even though it may just reflect an optimal response to idiosyncratic price fluctuations.

## 4 Empirical implementation

### 4.1 Results from international data

The source of our international data are the Penn World Tables of which we use release 6.1. (PWT 6.1.). Besides data from national accounts, the PWT also contain a set of deflators that have been constructed using a set of common international prices. This allows us to obtain an internationally comparable measure of the value of a country's output, i.e.  $gdp = p_s + y$ .

The PWT expresses all data in per capita terms. We generate the Rest-of-the-world (RoW) aggregate as the population-weighted mean. We construct measures of world-wide (RoW) GDP components using population weighted averages, where the population data is also from the PWT. Our analysis covers a panel of 22 industrialized countries over the period 1973–2000. Virtually all of the countries in the panel are OECD members and we sometimes refer to them under this label. Specifically, the countries in our cross-section are:

1. Canada, 2. the United States, 3. Japan, 4. Austria, 5. Belgium,
6. Denmark, 7. Finland, 8. France, 9. Germany (West), 10. Greece,
11. Ireland, 12. Italy, 13. Luxemburg, 14. Netherlands, 15. Norway,
16. Portugal, 17. Spain, 18. Sweden, 19. Switzerland, 20. United Kingdom,
21. Australia, 22. New Zealand.

<sup>10</sup>We note, however, that they are not analytically the same: in ASY and Sørensen and Yosha (1998), the variable with respect to which income and consumption are smoothed is  $\Delta \log Y$ , in our setup it is  $\Delta \log [P_s Y]$ . We empirically explore the importance of this difference in Section 4.4.

**Table 1** Price adjusted and quantity based risk sharing regressions

|                      | Price adjusted |        | Quantity based |        |
|----------------------|----------------|--------|----------------|--------|
| Coefficient estimate | 0.20           | (2.48) | 0.68           | (8.37) |

The price adjusted regression is  $\Delta cpi + \Delta c = \beta_u \Delta gdp + u$  the quantity-based regression is  $\Delta c = \beta_u \Delta y + v$ . Panel OLS estimates with country and time-specific fixed effects. Robust  $t$ -statistics based on Newey and West (1987) in parentheses

We start our empirical analysis by estimating our adapted version of the regional risk sharing regression (4) on international data. We then compare the outcomes to that obtained from the standard international risk sharing regression (3).<sup>11</sup> We take account of country specific fixed effects by removing the mean from each country-time series. By expressing all variables in growth rates relative to the rest of the world, we also account for time-specific fixed effects. We then estimate the risk sharing regressions by means of panel OLS. Throughout the paper, we report heteroskedasticity consistent standard errors based on Newey and West (1987).

In Table 1, the price-adjusted version of the risk sharing regression reveals a lot more risk sharing than the purely quantity based specification: the coefficient on the price adjusted equation is 0.20, whereas the coefficient of quantity-based regression is 0.68. The latter is completely in line with what is typically found in risk sharing regressions based on international data and suggests that only about a quarter to a third of all idiosyncratic country risk is smoothed or insured (e.g. Sørensen and Yosha 1998; Crucini 1999).

The price-adjusted risk sharing regression, on the other hand, reveals that taking account of differences in consumer prices and correcting for different price levels of GDP matters substantially for the amount of risk that is found to be shared. Our estimate of 0.20 is rather in the order of magnitude of the coefficient estimated from risk sharing regressions based on US state-level data (Asdrubali et al. 1996; Crucini 1999; Méltz and Zumer 1999).

In the following subsections we first attempt to identify what the channels of risk sharing are in the price adjusted setup and what the sources of this dramatic drop in the international risk sharing coefficient are. We then compare these findings to an implementation of the international, quantity-based regression (3) on regional data.

## 4.2 Prices vs. quantities?

Through which channels is the allocation of risk achieved once we take account of both relative price fluctuations and quantity flows? The variant of the ASY

<sup>11</sup>We will also refer to this regression as the quantity-based regression since it does not take account of relative consumer price variability. Furthermore, since for most countries the national GDP price deflator is highly correlated with CPI, regression (3) also the regressor reflects what are virtually pure quantities.

**Table 2** Channels of risk sharing

| Channel  |                 | Coefficient estimate |        |                |        |
|----------|-----------------|----------------------|--------|----------------|--------|
|          |                 | Price adjusted       |        | Quantity based |        |
| Quantity | $\beta_{inc}$   | 0.05                 | (1.52) | 0.04           | (1.19) |
|          | $\beta_{cons}$  | 0.27                 | (4.73) | 0.29           | (3.94) |
| Price    | $\beta_{price}$ | 0.48                 | (7.89) | –              |        |

The price adjusted regressions are regressions of  $\Delta y - \Delta inc$  ( $\beta_{inc}$ ),  $\Delta inc - \Delta c$  ( $\beta_{cons}$ ) and  $\Delta p_s - \Delta cpi$  ( $\beta_{price}$ ) on  $\Delta gdp$ . The quantity adjusted regressions are the same variables (except  $\Delta p_s - \Delta cpi$ ) regressed on  $\Delta y$ . On estimation details see Table 1

decomposition that we suggested in the previous section can shed light on this issue. In Table 2 we report the estimates of the  $\beta$ -coefficients. Half of all idiosyncratic risk is buffered by relative movements in the terms of trade and real exchange rates, our point estimate of  $\beta_{price}$  is 0.48. The two quantity-flow channels taken together account for only 30%. This suggests that relative dynamics in the internal terms of trade can account for most of the allocation of idiosyncratic risk, much more than do international capital flows.

For comparison, we also estimate a purely quantity-based decomposition of relative GDP growth, i.e. a version of the risk sharing regression where  $\Delta y - \Delta inc$  and  $\Delta inc - \Delta c$  are regressed on  $\Delta y$  instead of  $\Delta gdp$ . This is the regressions that is typically run on international data, when the data are deflated with the country-specific CPI. The second column of Table 2 reports the outcome of this exercise. Even though the regressor is quite different in the price-adjusted regressions, the point estimates for the  $\beta$ s associated with income and consumption smoothing respectively, are very similar in both the price adjusted and the pure quantity-based decompositions.

Hence, accounting for deviations from PPP and for terms of trade fluctuations does not alter our conclusions as to what extent international quantity flows contribute to international risk sharing. But it does provide a way to understand why international risk sharing generally appears so low: consumer and output prices covary systematically with idiosyncratic risk in OECD countries. This effect goes a long way towards explaining why most studies would find more risk sharing in regional than in international data.

#### 4.3 International vs. regional evidence from risk sharing regressions

We now study the relative importance of price and quantity dynamics for risk sharing by looking at regional data from a small group of countries, for which both real and nominal consumption and GDP data are available at the regional level. The countries and the sample of years for which we have data are: Australia (1990–2002), Canada (1980–2000), Italy (1960–96) and Germany (1996–2002). We provide details on the regional data in the [Appendix](#).

Only for Canada and Germany we have income measures at the regional level. Since the scope of our analysis is not to assess the relative importance

**Table 3** Relative role of price and quantity channels in regional data

| Country   | Quantity flows |         | Price           |        | Unsmoothed |        |
|-----------|----------------|---------|-----------------|--------|------------|--------|
|           | $\beta_q$      |         | $\beta_{price}$ |        | $\beta_u$  |        |
| Australia | 0.43           | (4.93)  | 0.50            | (5.34) | 0.70       | (0.78) |
| Canada    | 0.64           | (5.80)  | 0.16            | (2.02) | 0.18       | (2.93) |
| Germany   | 0.58           | (6.14)  | 0.01            | (0.19) | 0.42       | (3.55) |
| Italy     | 0.77           | (16.83) | 0.07            | (3.67) | 0.11       | (4.86) |

See Table 1

of the two quantity channels we just identify the sum of  $\beta_{inc} + \beta_c = \beta_q$  by regressing  $\Delta y - \Delta c$  on  $\Delta gdp$ . Table 3 provides the estimates of  $\beta_q$  and  $\beta_{price}$  as well as of the unsmoothed part,  $\beta_u$ , for the four countries.

In as far as the size of the unsmoothed component  $\beta_u$  is concerned, our estimates provide a wholesale confirmation of those obtained by ASY and others for U.S. data: roundabout three quarters of all idiosyncratic risk is shared among the regions of a country. While small relative to the standard international quantity regression, the non-insured component is generally significant.

As becomes apparent, the price channel contributes a lot less to risk sharing than it does in international data. This may not appear too surprising since persistent difference in particular in consumer price inflation are a feature rather of international than of regional data. But it is noteworthy that the price effect, though small, is significant in all countries except Germany.<sup>12</sup>

These results confirm our previous conjecture: controlling for relative price effects in international data reveals a much smaller deviation from the complete markets outcome than is commonly found using what we call a quantity based regression. Eventually, the allocation of risk is comparably efficient to that in regional data. What is different are the *channels* of risk sharing at the regional and the international levels.

Our interpretation of these findings is that goods markets are more integrated among the regions of a country than among countries and therefore consumer price differentials are small. Equating the value of marginal utilities across regions therefore virtually amounts to equating real marginal utilities which in turn requires big quantity flows. On the other hand, optimal risk sharing contracts between countries will take account of the fact that goods markets are very segmented internationally. Lane and Milesi-Ferretti (2004) provide evidence that countries that trade a lot with each other also have

<sup>12</sup>For Australia, the data reveal relative roles of quantity and price channels that are comparable to what we have obtained from international data. While this is an interesting result, we note two things: first, our sample for Australia is rather short. Second, to obtain measure of the regional GDP deflator, we had to use an experimental volume chain index for real state-level GDP. The Australian Bureau of Statistics issues a note of caution regarding the use of this series. We would therefore not overemphasize this particular result.

larger cross-holdings of financial assets. One reason for this may be that trade eliminates price differentials and therefore, consumption insurance can ultimately only be achieved through a diversified portfolio of financial assets.<sup>13</sup>

Interestingly, some authors have also documented a quantity anomaly—a high comovement between relative consumption and output—in regional data. Hess and Shin (1998) find that regressions for US state-level income and consumption yield coefficients near unity, not unlike the quantity-based risk sharing regressions obtained from international data. Del Negro (2002) confirms the results obtained by Hess and Shin and claims that the high levels of risk sharing identified by Asdrubali et al. (1996) can be explained by measurement error in the ASY data set.

Again, it seems that the principal difference between those studies that find a quantity anomaly and those that find high levels of risk sharing in regional data lies in the way they deflate the data. Asdrubali et al. (1996) and Crucini (1999) deflate gross state product (the state level equivalent of GDP) with the consumption price index whereas Hess and Shin deflate GSP with the respective state GSP-deflator. Sørensen and Yosha (2007) argue that the right way to deflate quantities in risk sharing regressions is with the CPI: the endowment risk of an economy is the value of its GDP in terms of the country's consumption basket. This implies that nominal output should be deflated with the CPI. The present paper has extended this logic in two important respects: first, we have argued that the data should be deflated with the area-wide ('common') CPI so that fluctuations in relative consumption price levels are preserved. Secondly, in international data it may also be important to use international prices to price output. We turn to a further discussion of this second point in the next subsection.

#### 4.4 The role of international prices

In order to adapt the regional risk sharing regression, we have used a common set of international GDP deflators. The primary reason for doing so was that this is also the practice how GDP is valued in regional data. There is also a theoretical justification for following this approach: the maintained

<sup>13</sup>To the extent that trade eventually eliminates price differentials, we should expect the role of the price channel in international data to decline in the long-run, quite in line with a growing literature that suggests that purchasing power parity may ultimately hold. Following Becker and Hoffmann (2006), I therefore examined the role of relative price variability at long horizons by performing the variance decomposition suggested above in the levels of the variables instead of first differences. As discussed in this earlier paper, this regression constitutes a long-run panel relation in the sense of Phillips and Moon (1999). Hence, even though the individual time series may be non-stationary and may not necessarily be integrated, there is no risk of spurious regression. The results of this exercise provide strong support for the interpretation above: in the long-run relative price fluctuations play a much smaller role for risk sharing. In international data, I now estimate  $\beta_{price} = 0.05$ . Though still significant, (*t*-statistics: 2.37) this is much smaller than the corresponding  $\beta_{price}$  estimated from first differences in Table 2. Conversely, quantity flows keep up quite well in the levels specification and the *ex ante* channel even gains in importance. ( $\beta_{inc} = 0.10$  (*tstat* = 2.54) and  $\beta_{cons} = 0.23$  (*tstat* = 4.59)). I thank an anonymous referee for suggesting this exercise.

**Table 4** Role of international GDP price deflators

| Channel  | Coefficient estimate |      |        |
|----------|----------------------|------|--------|
| Quantity | $\beta_{inc}$        | 0.04 | (1.20) |
|          | $\beta_{cons}$       | 0.29 | (3.94) |
| Price    | $\beta_{price}$      | 0.32 | (4.20) |

Regressions of  $\Delta y - \Delta inc$  ( $\beta_{inc}$ ),  $\Delta inc - \Delta c$  ( $\beta_{cons}$ ) and  $-\Delta cpi$  ( $\beta_{price}$ ) on  $\Delta y$ . On estimation details see Table 1

hypothesis in all of the risk sharing literature running regressions such as Eq. 1 is that international flows can, in principle, generate an allocation in which consumption can be made completely independent of output. This implies that output is perfectly tradeable. But in making this assumption, we should also impose a common set of prices to value this output rather than national GDP price deflators. On the other hand, consumption in country  $k$  has to take place in country  $k$ , so that the price level that is relevant for consumers in country  $k$  is not an international price but a local currency-price.<sup>14</sup>

One issue that may arise in this context is that the PWT's set of international GDP prices could be subject to measurement error, plausibly on a larger scale than are regional output price levels. This could lead to attenuation bias since relative growth in the value of GDP is the regressor in all our regressions. Secondly, it may be interesting to explore to what extent the choice of GDP deflator contributes to the price channel: is it relative consumer price variability or are our findings induced by fluctuations in  $\Delta p^s$ ?

We address these issues jointly by running all regressions of the extended ASY decomposition above with real rather than nominal relative GDP growth as regressor, i.e. we take out any effect that derives from valuing output at international prices by using  $\Delta y$  instead of  $\Delta gdp = \Delta p^s + \Delta y$ .<sup>15</sup> Comparing the results, given in Table 4, to the price adjusted regressions in Table 2 shows that this has virtually no effect on the coefficients of the quantity channels, a strong indication that measurement error cannot be a problem since it should lead to attenuation bias in both the regressions for the quantity and the price channels. The coefficient on the price channel decreases somewhat. The obvious interpretation is that in the price regression in Table 2, the term  $cov(\Delta p_s - \Delta cpi, \Delta p_s)$  is positive; fluctuations in  $\Delta cpi$  not only shield consumption from fluctuations in output quantities but also from ups and downs in the international terms of trade,  $\Delta p_s$ . This again suggests that our results reported above are largely driven by international variation in inflation differentials and only to a very limited extent by the choice of output price deflator.

<sup>14</sup>At a theoretical level, our approach could be justified by a model in which output consists of intermediate inputs that are highly tradeable internationally. These outputs can then either be traded or be transformed into an imperfectly tradeable consumption good.

<sup>15</sup>I thank George von Fuerstenberg for suggesting this course of analysis.



#### 4.5 The relation between real exchange rates and consumption

I conclude my analysis by relating my results to another strand of the literature that—starting with Backus and Smith (1993)—has emphasized that optimal risk sharing implies a high correlation between real exchange rates and consumption if consumer prices do not equalize across countries. This literature has found it difficult to document any robust link between these two variables. As we have argued earlier in the context of the quantity puzzle, international consumption correlations may be low for reasons that are unrelated to market incompleteness. The same reasons could explain why the correlation between consumption and real exchange rates—and in regional data between inflation differentials and consumption—is so low.<sup>16</sup> In international data, the problem of finding a meaningful correlation between exchange rates and consumption is likely to be compounded by the exchange rate disconnect puzzle. I illustrate these issues in Table 5: even in what we would believe is a financially well-integrated area—the regions of a country—and even after the elimination of nominal exchange rate variability, the link between relative inflation and consumption is weak.

The table reports the results of regressions of inflation differentials and real exchange rate changes on real idiosyncratic consumption growth, both for the international but also for the four regional data sets described above. In international data, the coefficient estimate for the inflation differential regression is  $-0.20$ , whereas the coefficient for the real exchange rate regression is  $0.16$ . Whereas the first coefficient is highly significant, the second is not. The average

**Table 5** Inflation differentials, real exchange rate changes and relative consumption

|            |                         | Regression on $\Delta c$ |           |         | Average correlation with $\Delta c$ |
|------------|-------------------------|--------------------------|-----------|---------|-------------------------------------|
|            |                         | coeff.                   | t-stat    | $R^2$   |                                     |
| Intl' Data | $\Delta cpi$            | $-0.20$                  | $(-2.84)$ | $0.04$  | $-0.19$                             |
|            | $\Delta cpi - \Delta e$ | $0.16$                   | $(1.14)$  | $0.004$ | $0.04$                              |
| Australia  | $\Delta cpi$            | $-0.05$                  | $(-2.11)$ | $0.04$  | $-0.19$                             |
| Canada     | $\Delta cpi$            | $-0.03$                  | $(-2.41)$ | $0.02$  | $-0.14$                             |
| Germany    | $\Delta cpi$            | $-0.05$                  | $(-1.15)$ | $0.03$  | $-0.18$                             |
| Italy      | $\Delta cpi$            | $-0.142$                 | $(-3.07)$ | $0.04$  | $-0.23$                             |

Notes: The average correlation is  $\frac{1}{K} \sum_{k=1}^K \text{corr}(\Delta c_k, \Delta p_k)$  where  $k$  is the number of regions or countries. For notes on regression results see again Table 1

<sup>16</sup>Indeed, market incompleteness alone may not even be sufficient to rationalize the correlations between consumption and real exchange rates that is typically found in the data. Baxter and Crucini (1995) have demonstrated that the equilibria in complete market economies are almost identical to those of a bonds-only economy, unless shocks get very persistent. As argued by Corsetti et al. (2004), it may therefore be rather difficult to generate realistic correlations between real exchange rates and consumption through market incompleteness alone.

(across countries) correlation of relative consumption growth and inflation differentials is  $-0.19$ , the average correlation between real exchange rates and consumption virtually zero. Regressing inflation differentials on relative consumption growth in regional data, we obtain on average coefficients that are even lower (in absolute value) than in international data. The average correlation ranges from  $-0.14$  to  $-0.23$ . The  $R^2$  statistics are low in all regressions.

Hence, there is virtually no relation between real exchange rates and consumption at the international level, quite in keeping with results in Backus and Smith (1993) and elsewhere. But the results from regional data show that even the elimination of nominal exchange rate variability in financially well integrated areas does not help to establish a particularly pronounced link between the two variables. In fact, once we abstract from nominal exchange rate variability in international data, the link between inflation differentials and consumption is no stronger in regional than in international data. These findings seem to suggest that the Backus–Smith condition gives us an important theoretical puzzle to solve, but it also seems to teach us that the consumption–real exchange rate correlation may have relatively little to say about the extent of risk sharing.

## 5 Discussion and conclusion

A lot more risk is shared among the regions within a country than among countries. This is the evidence from a well-established literature that has looked at risk sharing regressions, i.e. regressions of idiosyncratic consumption growth on idiosyncratic output growth. This paper has argued that the way in which the data have been deflated in risk sharing regressions when applied to international data is conceptually different from the way in which regional data are deflated in such cases: whereas international data are deflated with country-specific CPIs, regional data have mostly been deflated with the country-wide (i.e. a common) CPI. The latter approach leaves relative price movements intact, whereas the former eliminates them. But relative price movements are important from a risk sharing perspective and they may be particularly so *between* countries, where consumer price movements are known to be much more idiosyncratic than among the relatively well-integrated regions *within* a country.

Our results suggest that accounting for this price channel can indeed explain why there is an apparent lack of risk sharing between countries. It seems that consumption allocations observed between countries are not as far away from an optimal allocation (of risk) as is often thought. Movements in the relative price levels of consumption and output account for a lot of the departure from the full risk sharing allocation at the international level. Still, our results corroborate the findings by Sørensen and Yosha (1998), Crucini (1999), Becker and Hoffmann (2006) and others that quantity (income and credit) flows between countries are small relative to quantity flows between regions. Certainly, in this respect there *is* a lack of international risk sharing.

But our interpretation of these findings is that *goods* markets—rather than *financial* markets—are a lot more segmented between countries than between regions. The more segmented goods markets are, the higher the dispersion of prices across regions or countries will generally be. And the more the price of consumption can differ across countries, the less quantity flows are needed to optimally share risk: if it is costly to ship goods, then other things equal, optimal financial contracts will minimize the shipment of capital (and therefore ultimately: goods) between countries. If prices do not equalize between countries or regions, then consumption should be relatively high when prices are relatively low.

These findings are consistent with a recent strand of the theoretical literature that emphasizes that frictions in international goods markets may be the main ‘culprits’ behind the major quantity anomalies in international macroeconomics (see notably Obstfeld and Rogoff (2000)). They can also help understand the empirical regularity—recently highlighted by Lane and Milesi-Ferretti (2004)—that countries’ international asset portfolio weights are highly correlated with their trade weights: among countries that have highly integrated goods markets and therefore quite similar consumption prices, capital income and credit flows will be needed to achieve an efficient allocation of consumption risk. Therefore, one may expect these countries to have more substantial cross-holdings of financial assets than pairs of countries for which relative price dynamics plays an important role in allocating idiosyncratic risk.

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## Appendix

### Regional data sources

**Australia:** All data are from the Australian Bureau of Statistics and are available at the state level. The CPI data are the CPIs of the respective eight capital cities. Consumption and output are obtained from the breakdown of state level GDP by expenditure and are mid-year estimates (June), ranging from 1990–2002. Income is real gross state domestic income, 1992–2002.

**Canada:** The data are from Statistics Canada. The data series are personal income, retail sales, population, GDP and CPI by province and range from 1981–2002.

**Germany:** All data are from the Statistisches Bundesamt, at the federal state level for all 16 federal states. The data range is 1990–2002.

**Italy:** We used the REGIO-IT data set from the Centro di Ricerche Economiche Nord Sud (CRENoS) at University of Cagliari. The data range from 1960–1996.

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